SUB-GEV AND OTHER RARE EVENT SEARCHES WITH THE LUX DETECTOR

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on behalf of LUX collaboration
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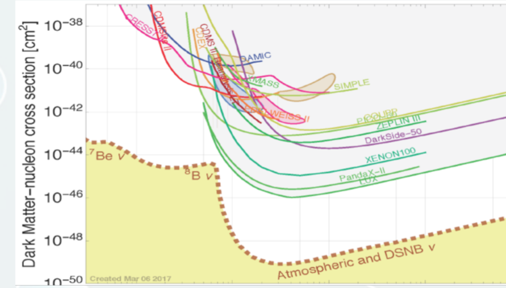
April APS in Columbus, OH. 14th of April, 2018

LUX detector is searching for dark matter



1 meV | 1 eV | 1 keV | 1 MeV | 1 GeV | 1 TeV

Axions

Axion-like particles

Light dark matter
+ light mediators

WIMPs

SIMPs

~meV energy detection

~eV energy detection

~keV energy detection

Absorption | Scattering

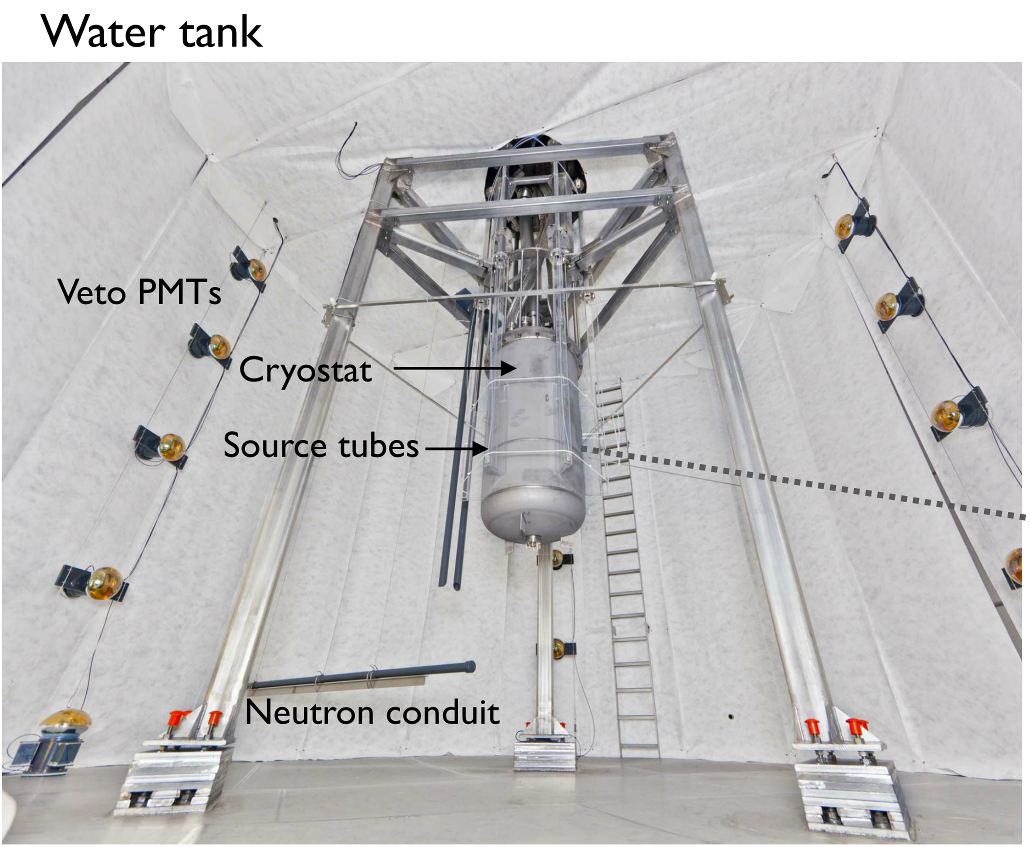
Illustration by Sandbox Studio, Chicago with Ana Kova

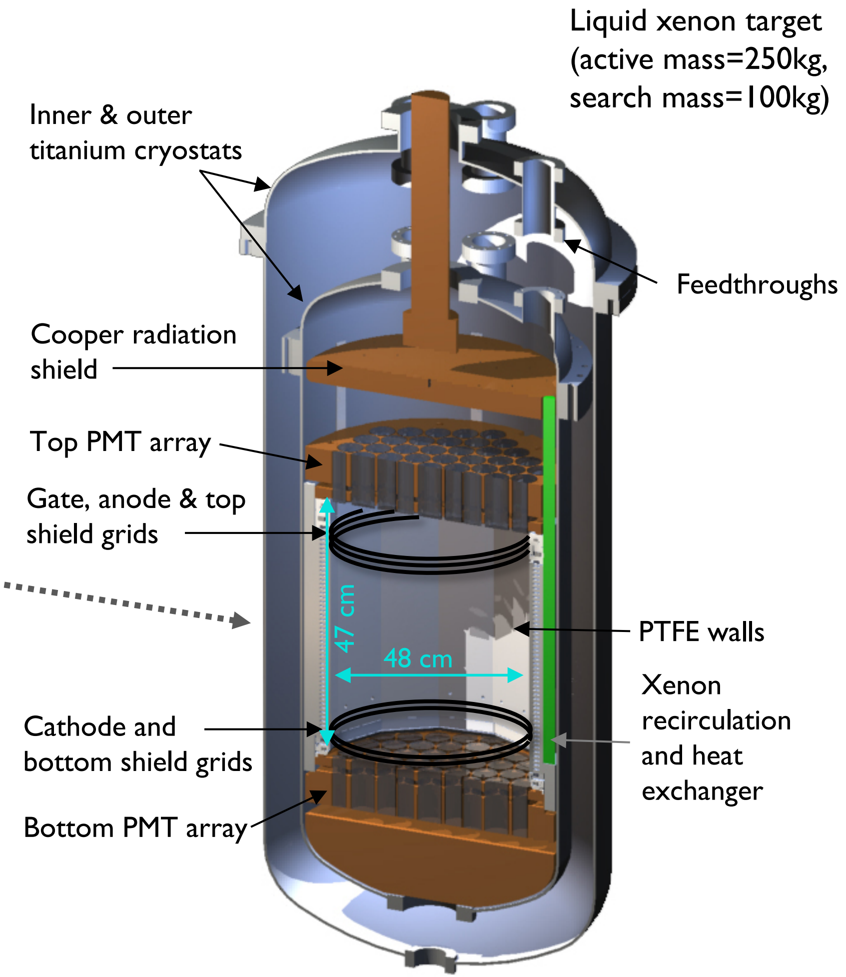
LUX collaboration

LUX =
Large
Underground
Xenon
Experiment

LUX collaboration meeting, June 2015
Sanford Underground Research Facility, Lead, SD

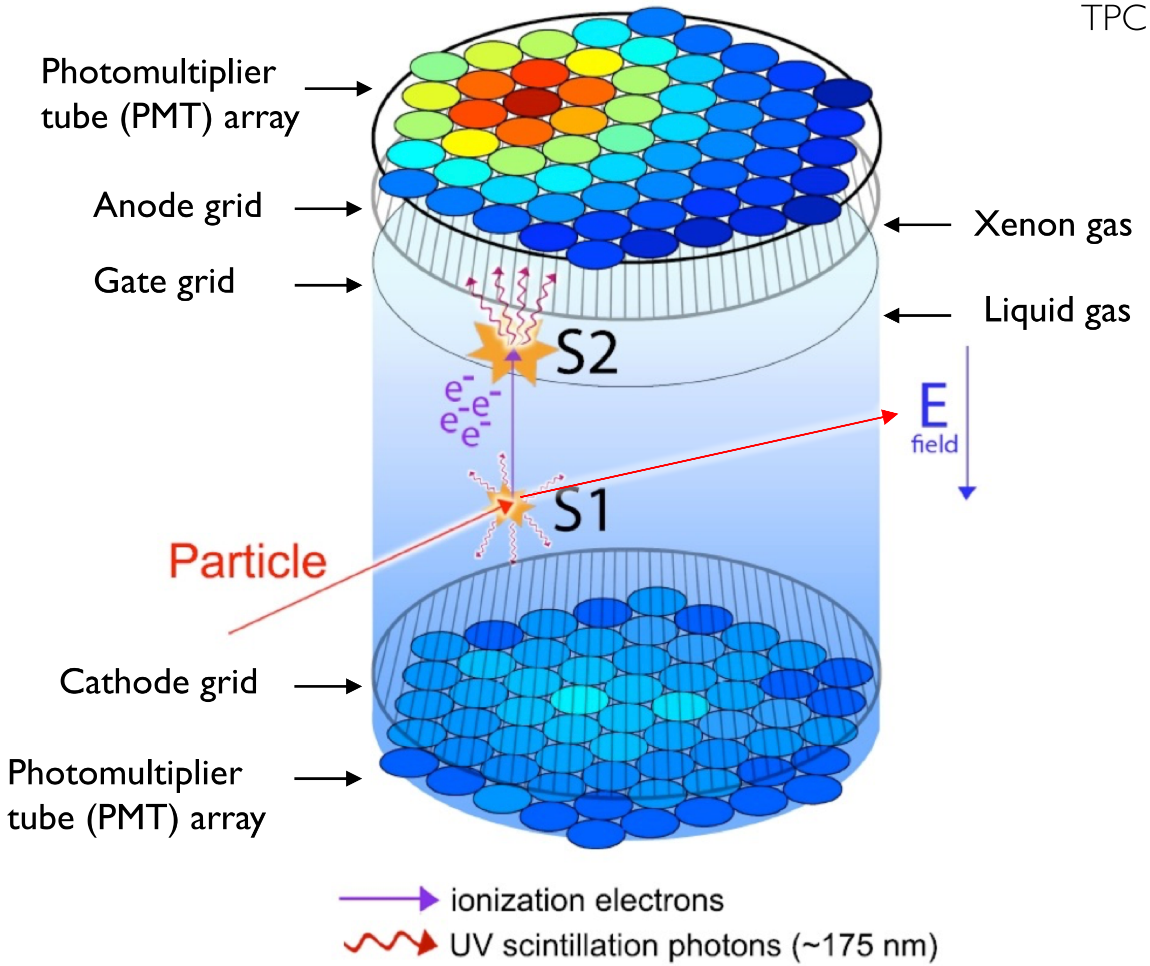
LUX detector operated 4850' (1478m) underground





Two phase TPC maps detector volume

TPC = Time Projection Chamber



LUX is a two phase TPC

Using xenon

- Spin-dependent & independent WIMP detection capabilities
- High atomic mass (A=131 g/mol)
- No intrinsic DM search backgrounds
- Scalable to multi-ton size

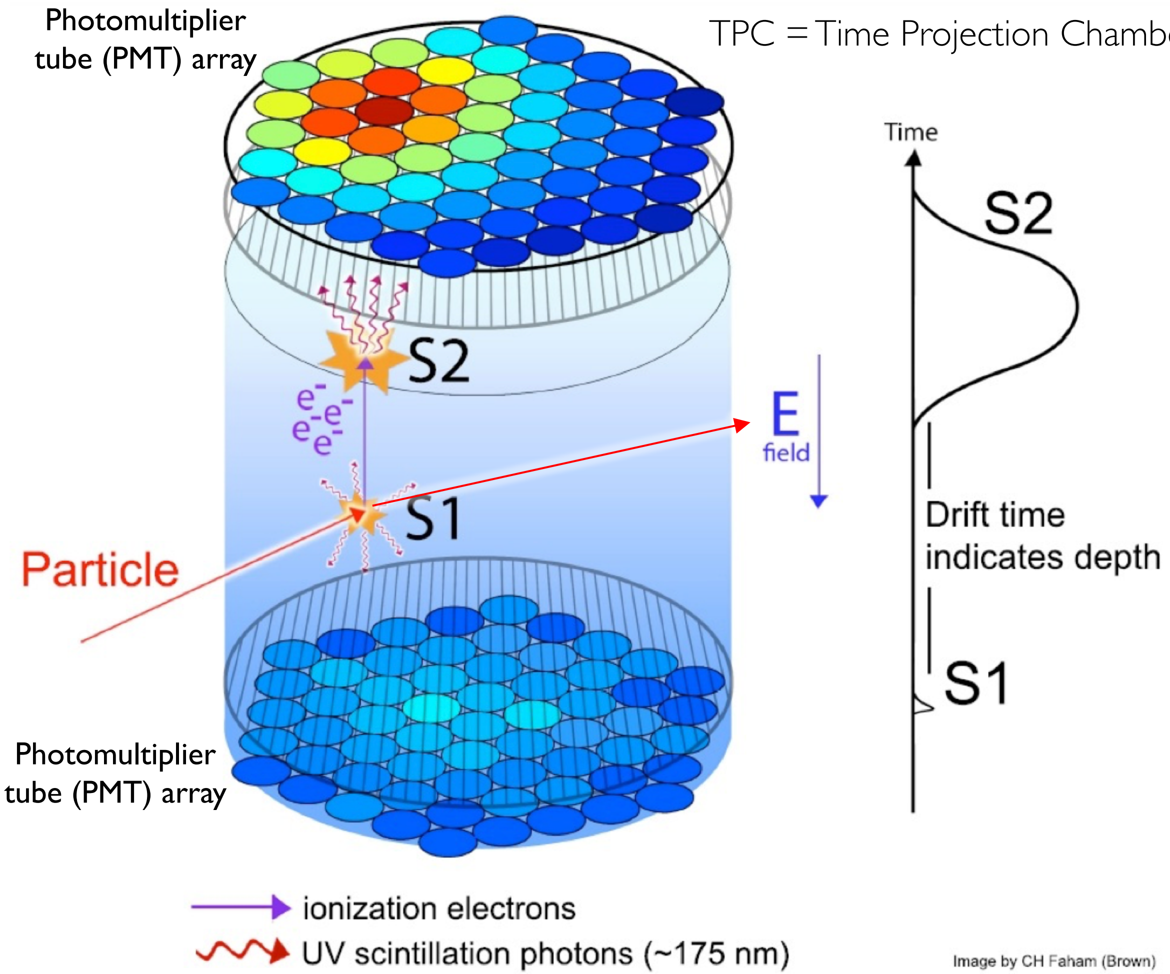
with full 3D position reconstruction

- *xy* reconstructed from S2 light pattern
- *z* given by time difference between S1 and S2

and S2/S1 discrimination

- Ability to reject backgrounds

TPC = Time Projection Chamber

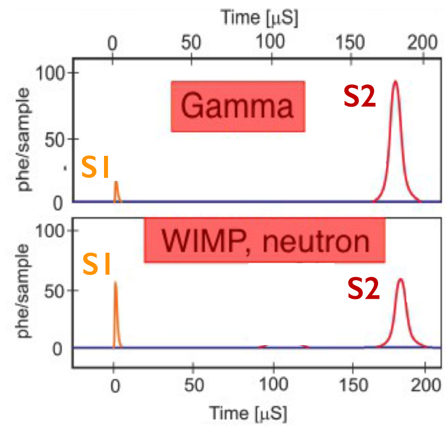


Distinguish between 2 types of particle recoil

Discriminate electron & nuclear recoils using S2/S1 ratio

S1 – light signal (178 nm photons)

S2 – charge signal (electrons)

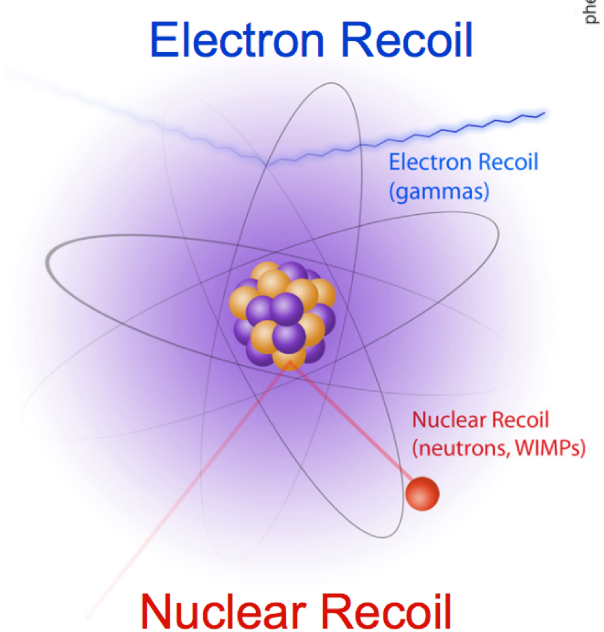


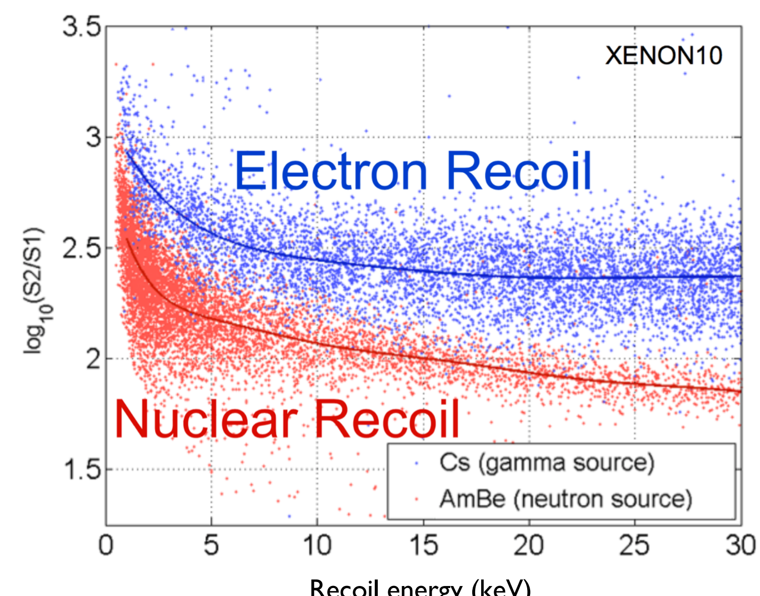
Electron recoil (ER)

- γ, B

Nuclear recoil (NR)

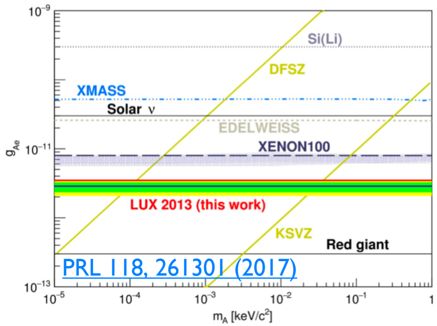
- Neutrons, WIMPs





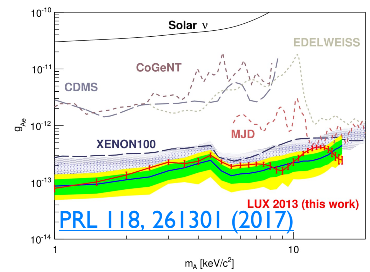
LUX data improved experimental boundaries

Axion limit



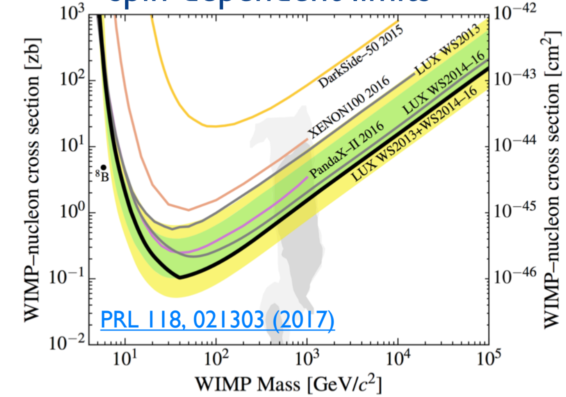
PRL 118, 261301 (2017)

Coupling between galactic ALPs and electrons



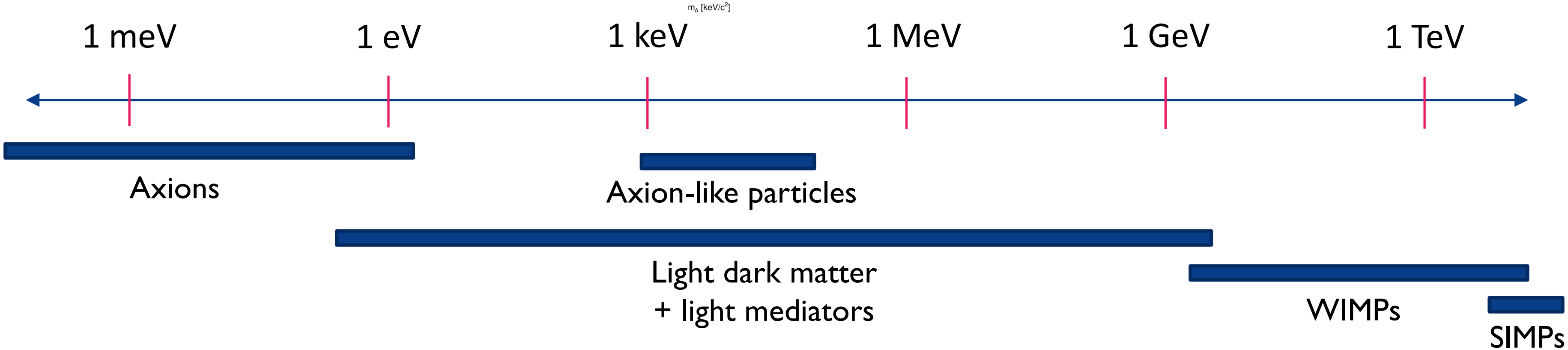
PRL 118, 261301 (2017)

Spin-independent & spin-dependent limits



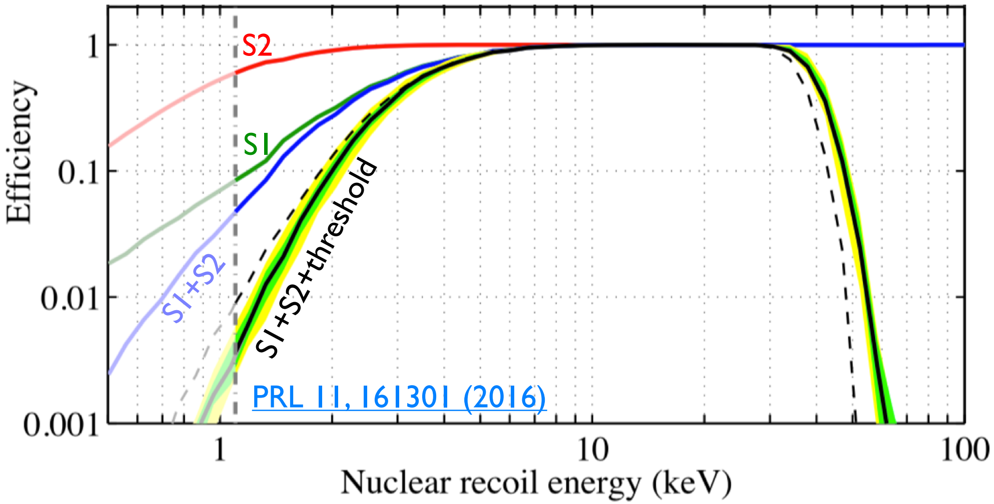
PRL 118, 021303 (2017)

& PRL 118, 251302 (2017)

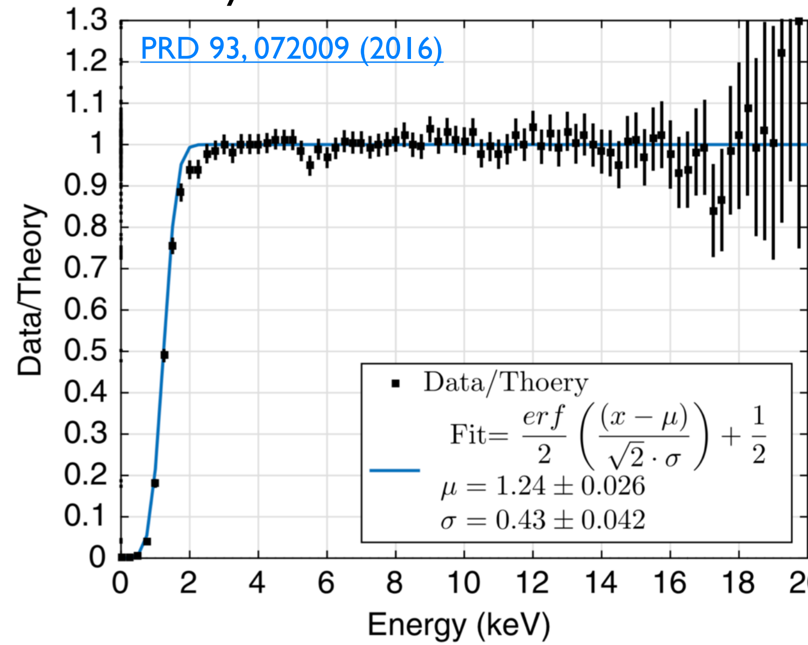


LUX is more sensitive to lower energies of electron recoils

Efficiency of nuclear recoil events in LUX in WS2013 reanalysis



Efficiency of electron recoil events in LUX

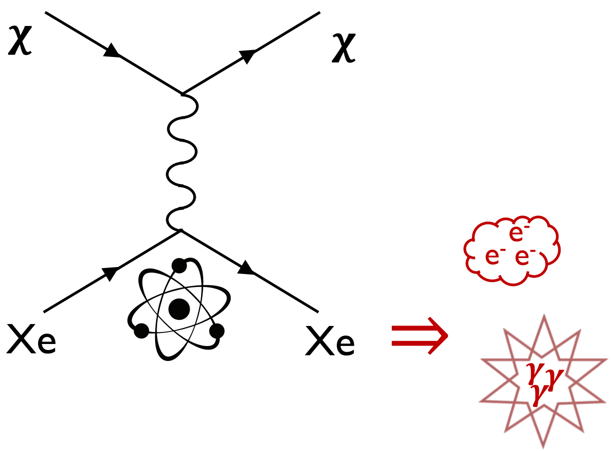


50% energy threshold:
nuclear recoils = 3.3 keV
electron recoils = 1.2 keV

LUX can detect sub-GeV DM via bremsstrahlung

Elastic scattering

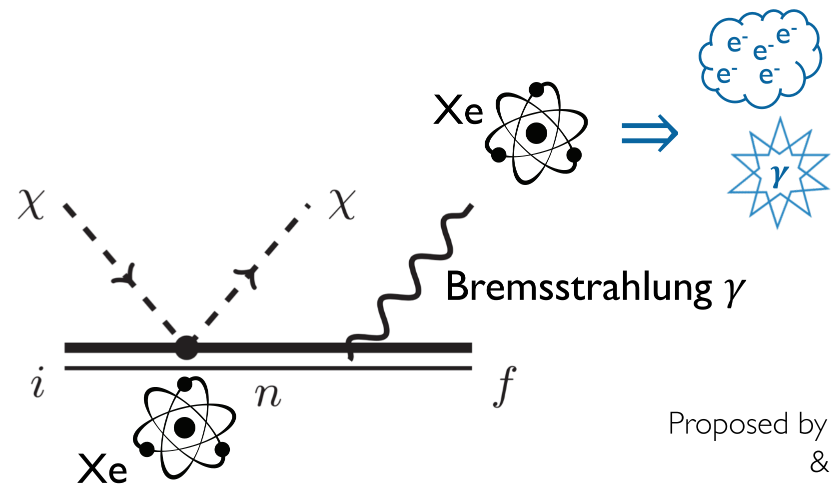
- Nuclear recoil signal
- Assumed in the standard WIMP search
- LUX searches for $m_{DM} \gtrsim 5\text{GeV}$



Bremsstrahlung

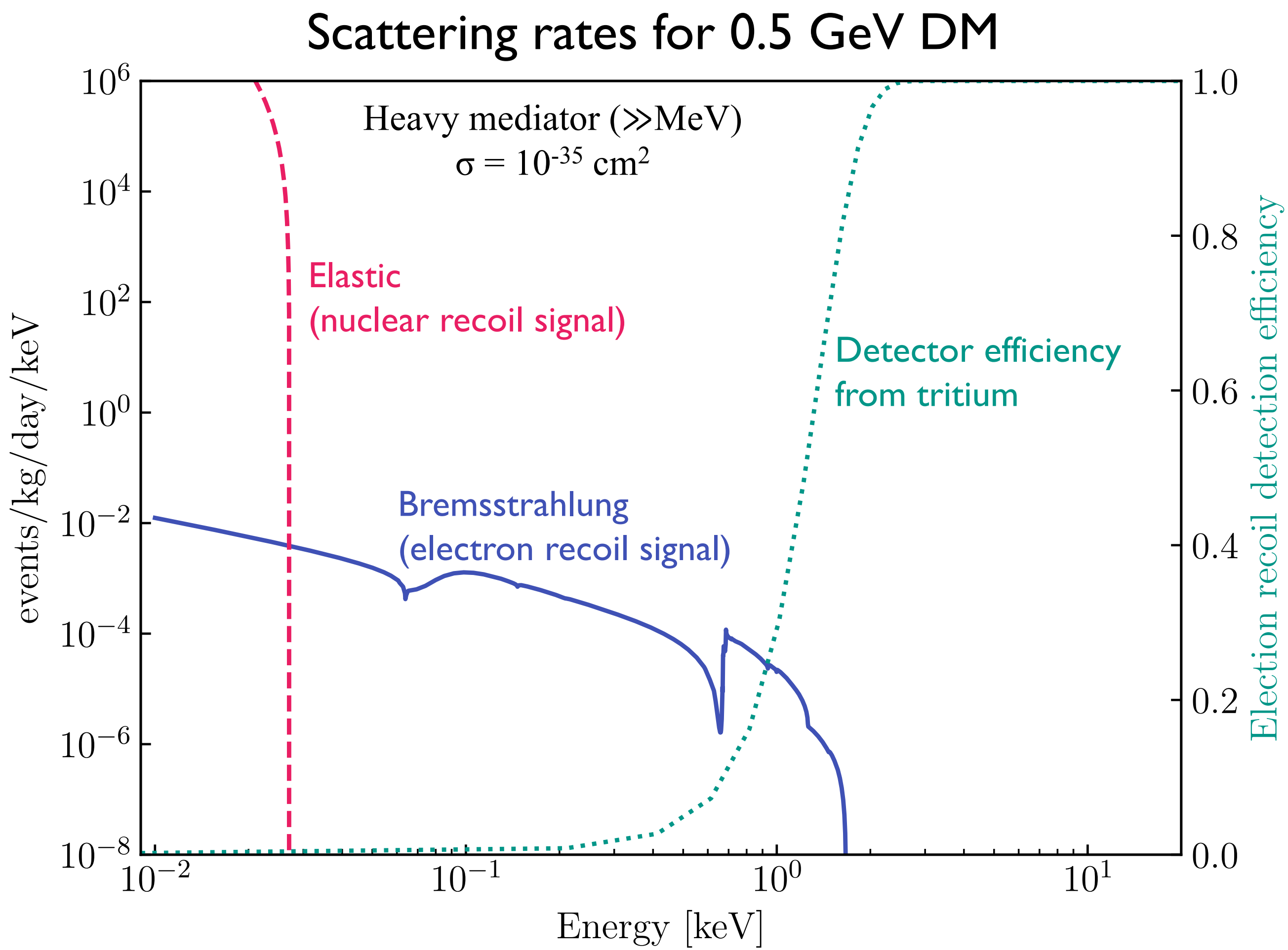
- Nuclear interaction, but electron recoil signal
- Emission of a photon from a polarized xenon atom
- Gain access to low energy NR interactions by looking for this ER signature since ER signal is much easier to detect at low energies!

⇒ LUX can gain sensitivity to $m_{DM} \sim \text{MeV}$



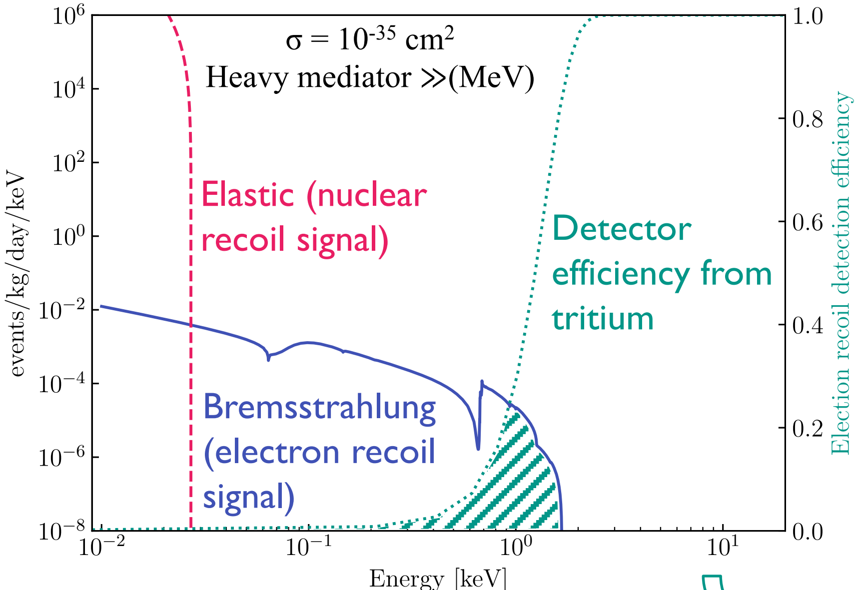
Proposed by C. Kouvaris & J. Pradler in [PRL 118, 031803 (2017)]

Bremsstrahlung allows detection of NR previously below threshold

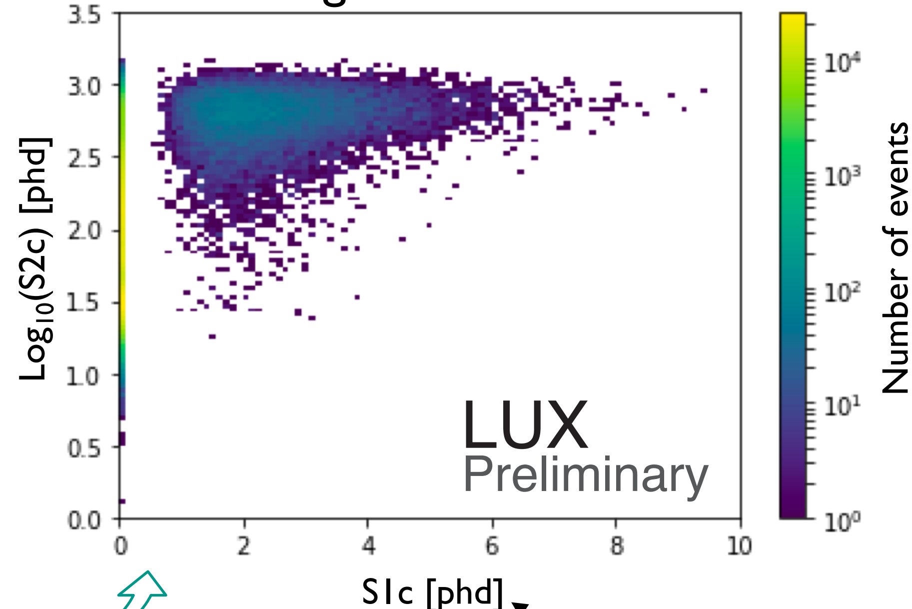


Example of a signal expected in LUX from m_χ = 0.5 GeV

Scattering rates



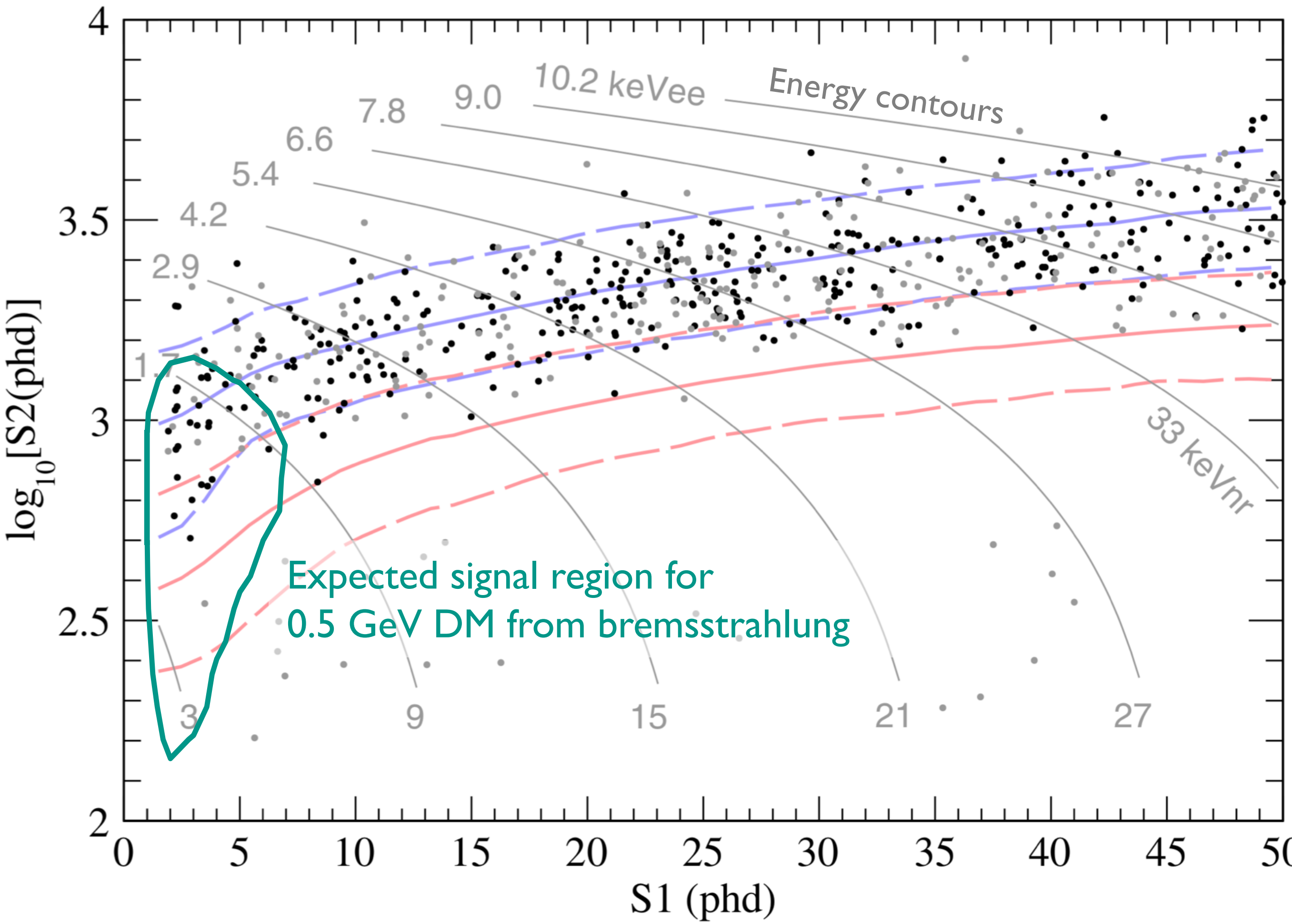
Expected bremsstrahlung signal in LUX



# of photons detected

Simulate events for these scattering rates using NEST (Noble Element Simulation Technique package)
JINST 8:C10003 (2013)

Final WS2013 data after cuts (95 live days)



Electron recoil band

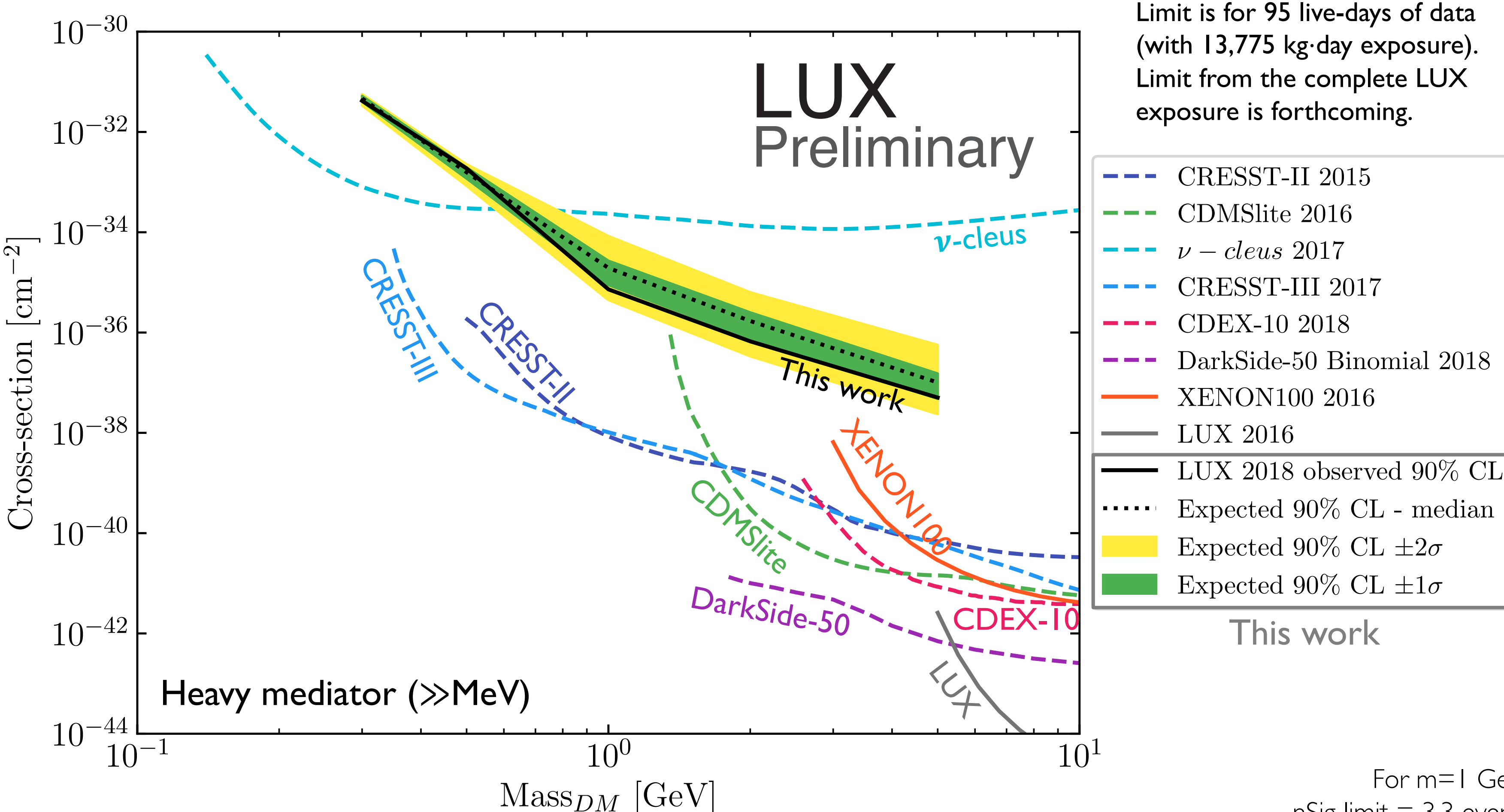
Nuclear recoil band for m_χ=50 GeV

Dashed lines are 10 & 90 percentiles

Black points: r ≤ 18 cm

Grey points: 18 < r < 20 cm (edges of the fiducial volume boundary)

LUX limit calculated using profile likelihood ratio



Limit is for 95 live-days of data (with 13,775 kg·day exposure). Limit from the complete LUX exposure is forthcoming.

For m=1 GeV:
nSig limit = 3.3 events

Conclusion

- Bremsstrahlung signal allows LUX to search for sub-GeV DM
- LUX sensitivity extends down to DM with masses of 0.3 GeV, providing the most stringent limit for LXe detectors for light DM
- Learn more about LUX & LZ at the April APS:
  - Session J09, Sunday 1:30pm
    - Signal yields in liquid xenon with LUX (V Velan)
    - Charge and light yields of liquid xenon using ^{14}C and tritium beta decay sources in LUX (J Balajthy)
    - Xenon circulation and liquid-level stability in LZ (D Temples)
    - Development of the LZ high voltage grids (R Linehan)
    - Status of LZ cathode high voltage research and design project (J Watson)
    - Recent results from the LZ System Test platform at SLAC (K Stifter)
  - Session J10, Sunday & Monday 1:30pm
    - Measurement of the Davis Cavern gamma-ray background at the Sanford Underground Research Facility (S Shaw)
    - Simulations of external backgrounds at SURF for the LUX and LZ experiments (D Woodward)
    - The active veto system for LUX and underground muon signals (D Tiedt)
    - The LZ liquid scintillator screener detector (S Haselschwardt)
    - Radiogenic backgrounds in the LUX xenon and detector components (K Mallory)

LUX collected data from 2013-2016

2006: LUX collaboration formed

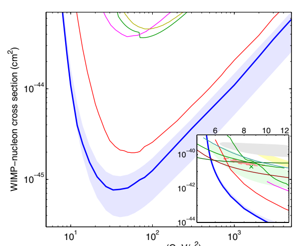
2008: LUX funded (DOE + NSF)

July 2012: LUX moves UG

April 2013: First science run starts

August 2013: Joined LUX

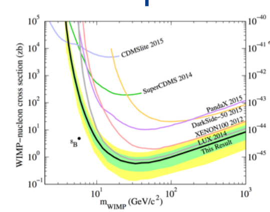
Nov 2013: First WS results reported (85.3 live-days)



PRL, 112, 091303 (2014)

Sept 2014: 332-day run start

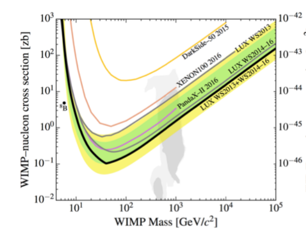
Dec 2015: Re-analysis of WS2013 published



PRL, 116, 161301 (2016)
PRL, 116, 161302 (2016)

May 2016: WS2014-16 finished

July 2016: 332-day WS result announced



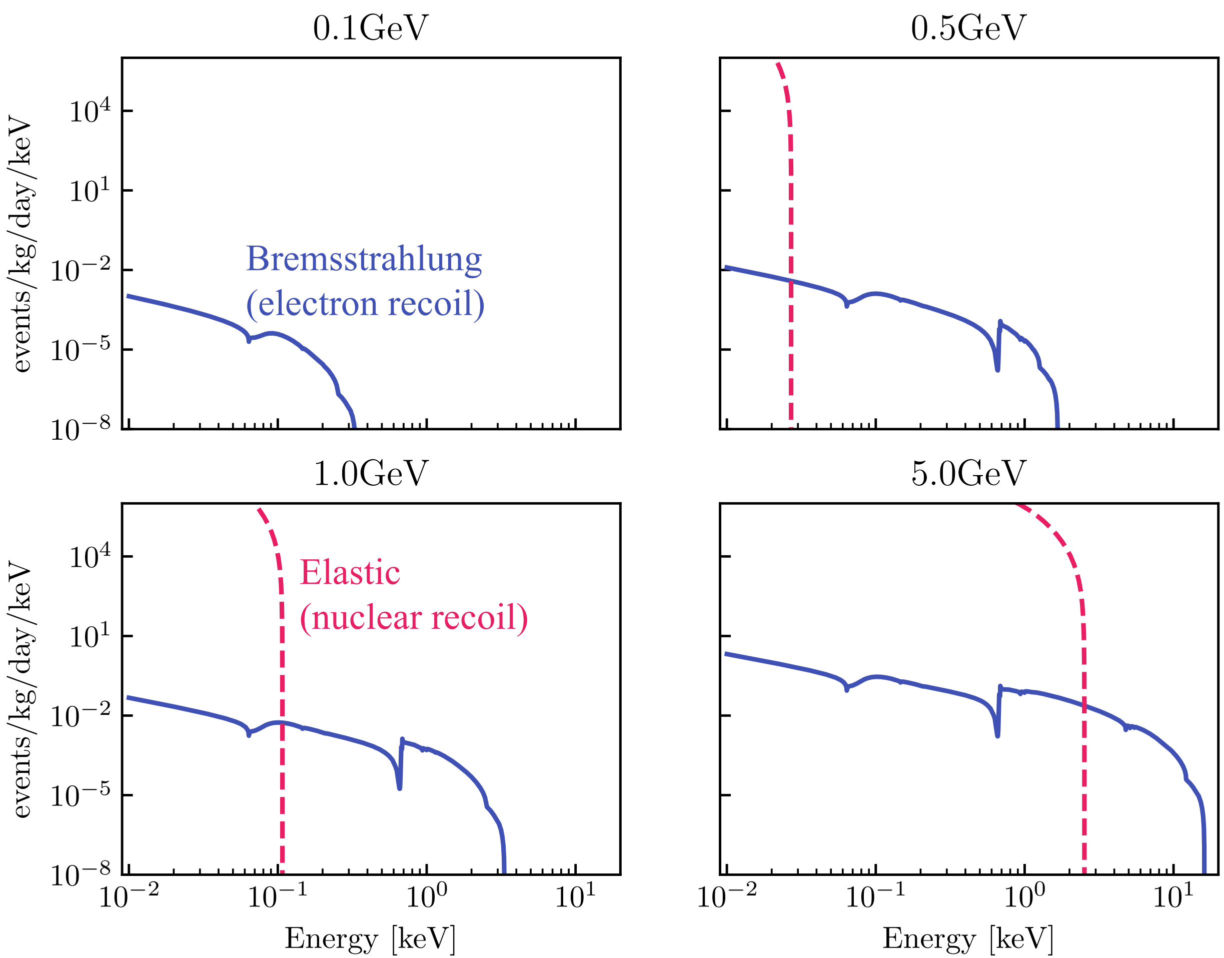
PRL, 118, 021303 (2017)

Sept 2016: decommissioning start

June 2017: LUX installed in a museum

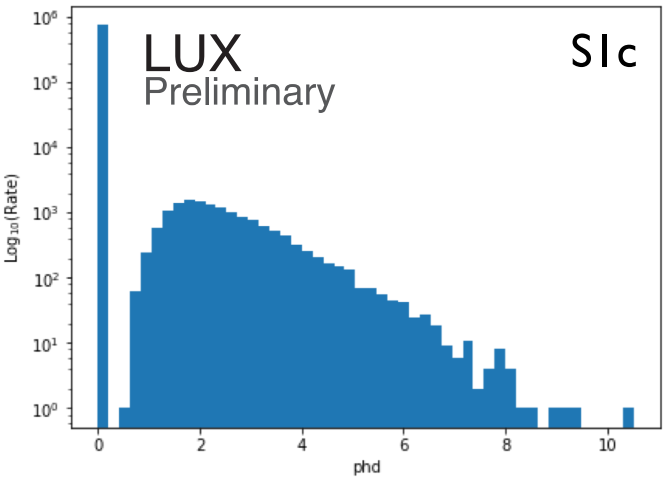
Analysis still ongoing

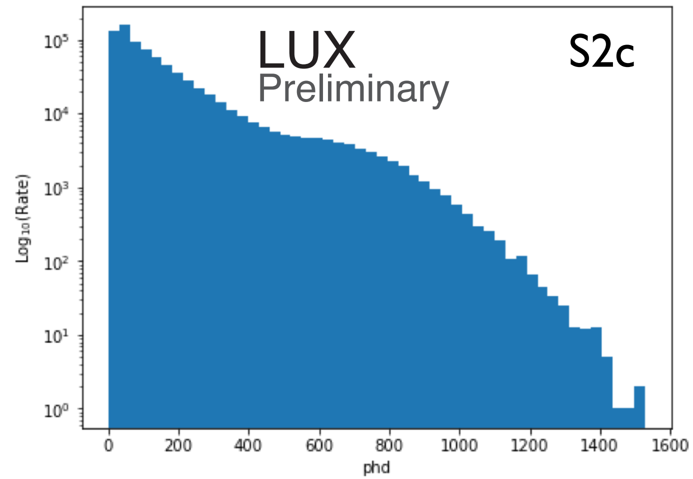
Expected scattering rates in xenon for σ = 10^{-35} cm^2

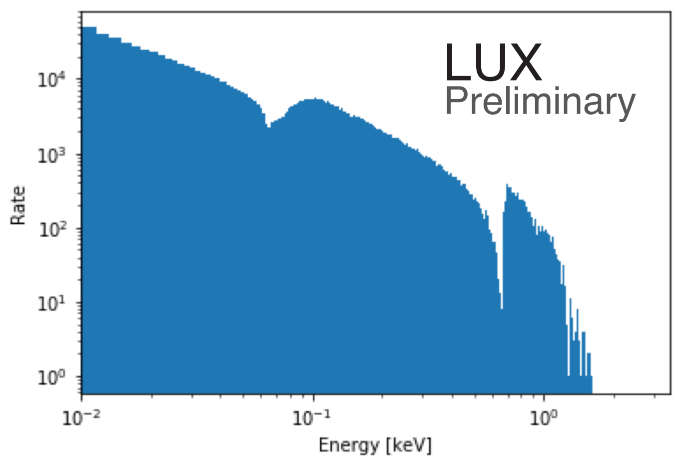


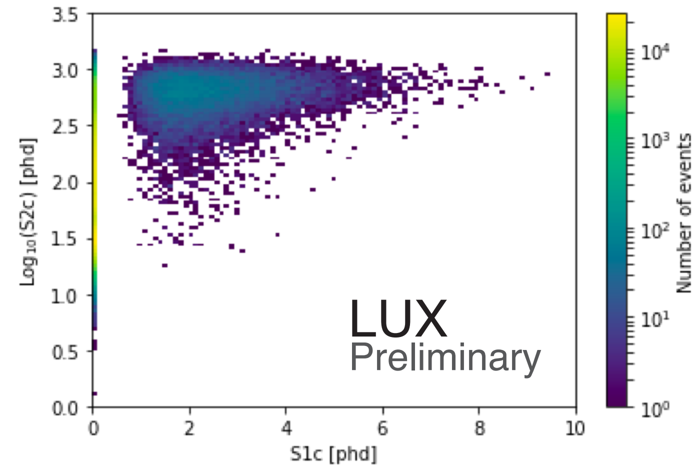
Photon emission rates in xenon were first calculated by C. Kouvaris & J. Pradler [PRL 118, 031803 (2017)](PRL 118, 031803 (2017))

Expected signal for m = 0.5 GeV DM from LibNEST

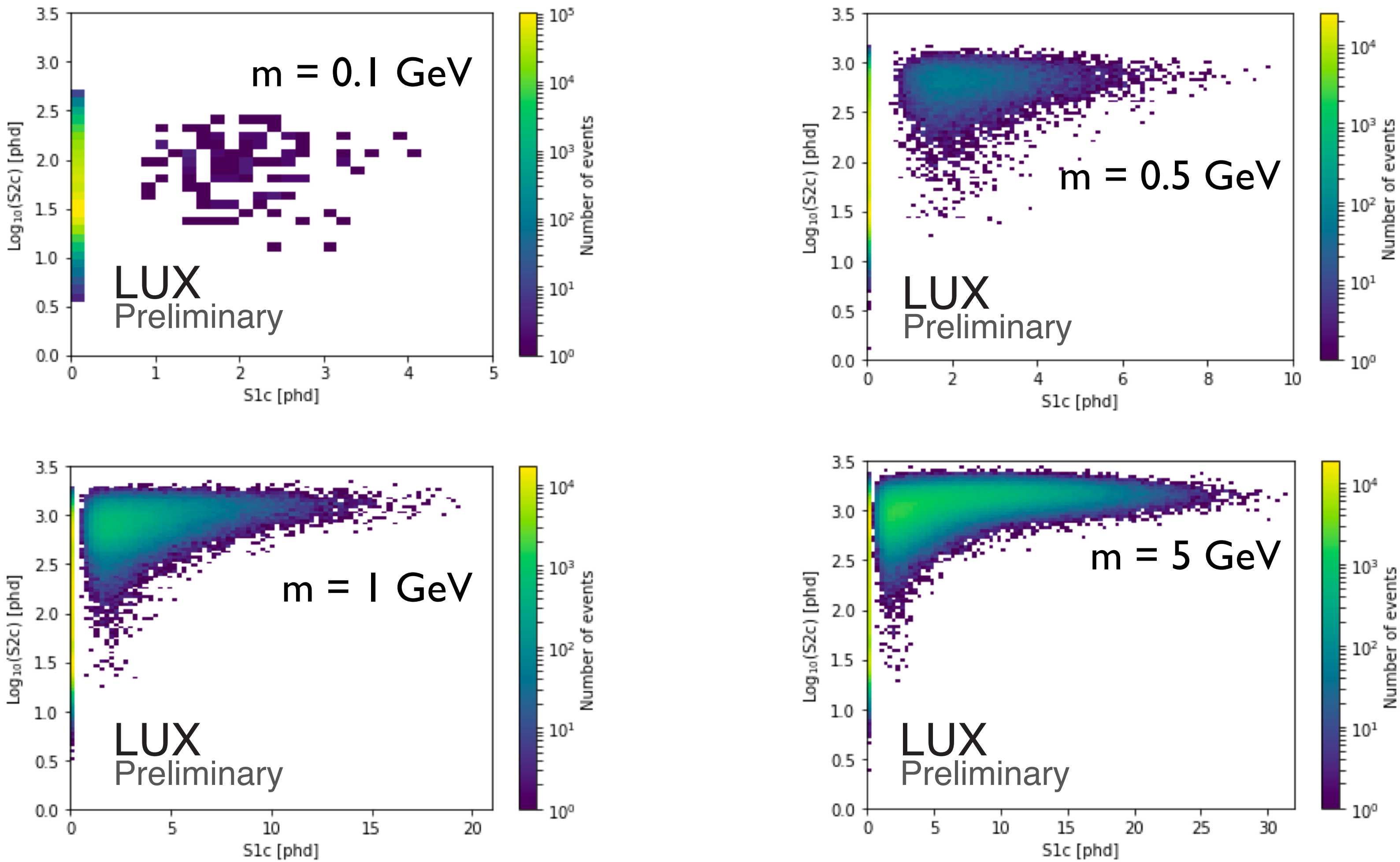




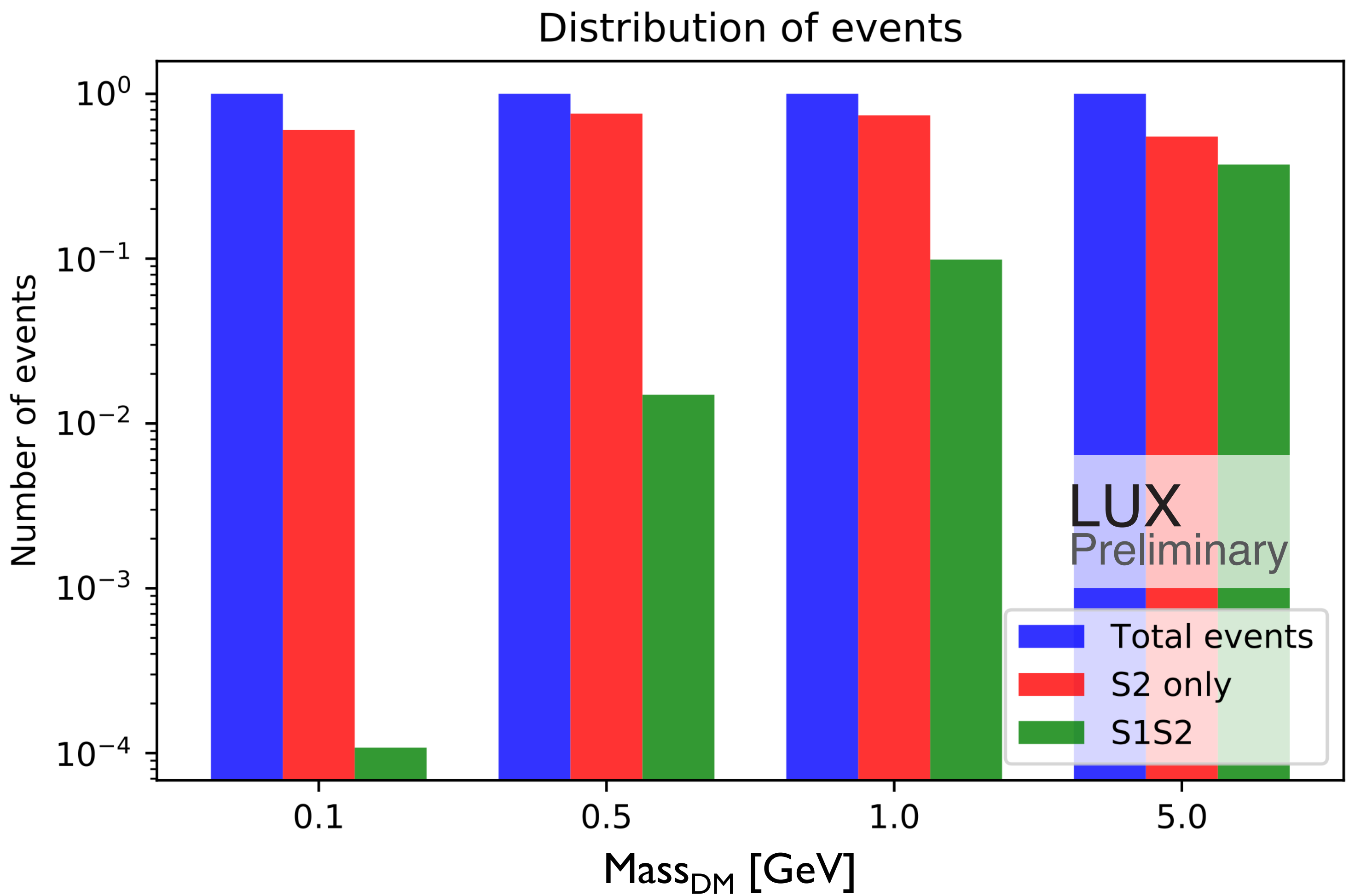




Expected signal spectra simulated by NEST at $\sigma=10^{-35}cm^2$



Only a fraction of events have both S1 & S2 signals

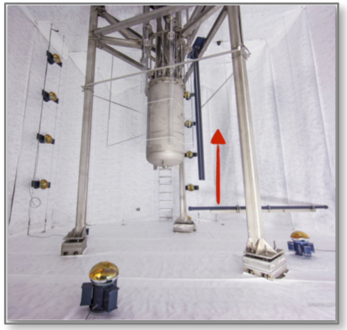


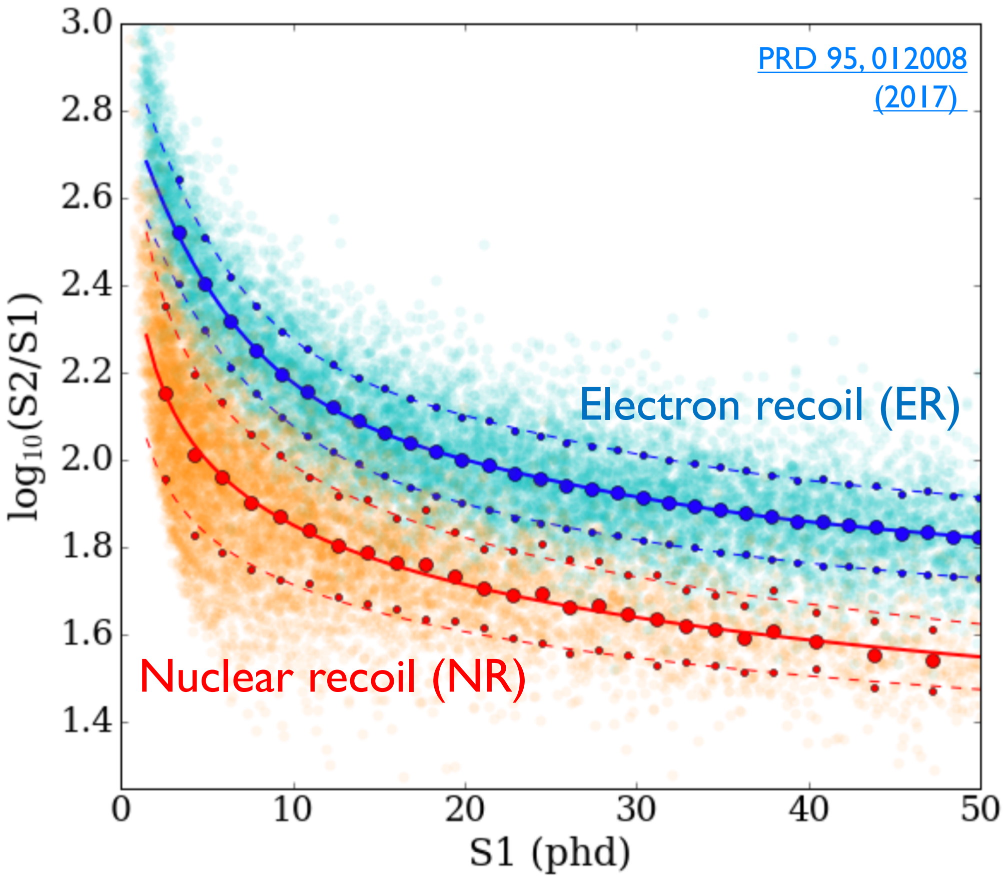
Tritium and DD calibrate detector response

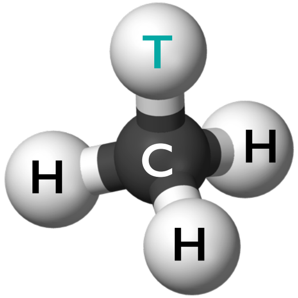
Deuterium-Deuterium neutron generator

- E = 2.45 MeV
- Located outside of the water tank
- Injected quarterly at different *z*
- Double scatters used for Q_y analysis
- Single scatters used for L_y analysis and NR band

arXiv:1608.05381







CH_3T

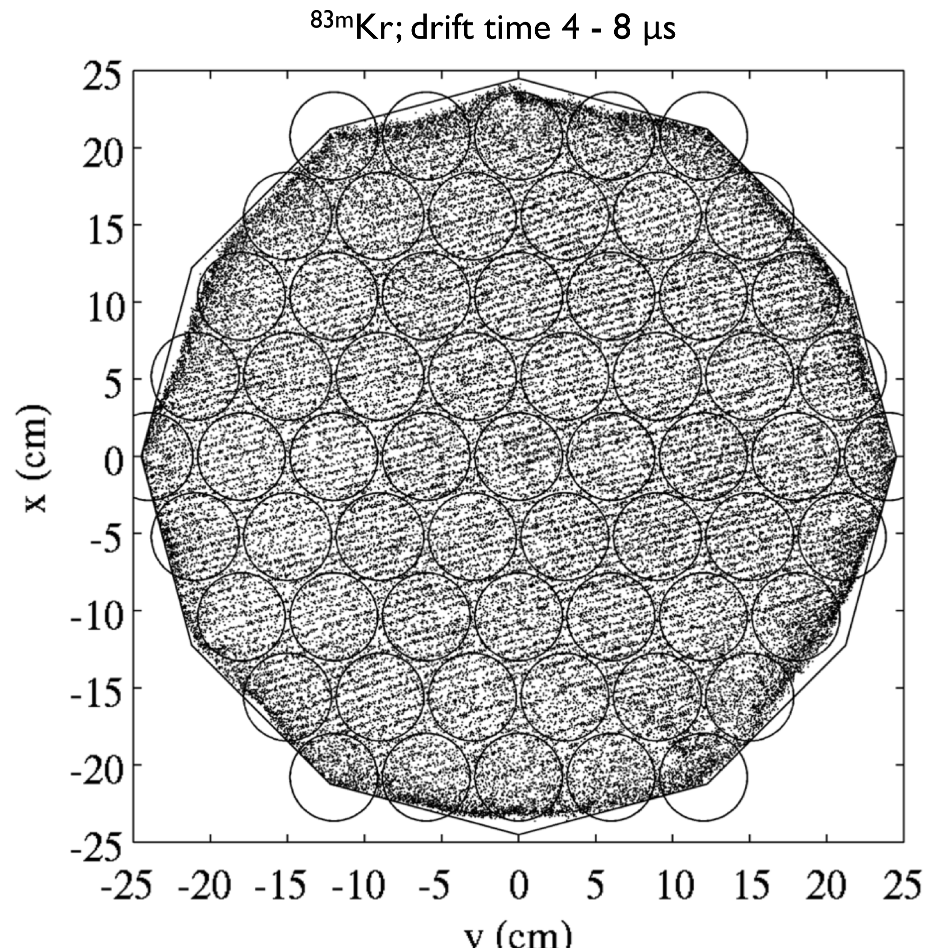
- Tritium β spectrum coincides with WIMP interaction energy
- $T_{1/2}$ = 12.3 yr
  - Removed by getter
- Injected quarterly

PRD 93, 072009 (2016)

^{83m}Kr monitors detector performance

[PRD 11.112009 (2017)]

- Krypton-83m is injected regularly into the detector to characterize detector response and monitor stability
- Mixes homogenously with LXe
- Used for:
  - Overall stability monitoring
  - Position reconstruction
  - Electron lifetime
  - S1 & S2 position corrections
  - Electric field modeling
- Decays by emitting 2 internal conversion electrons
  - 32.2 keV followed by 9.4 keV ($T_{1/2}$ = 154 ns)
  - Monoenergetic for our standard analysis
- $T_{1/2}$ = 1.83 h



LUX collaboration

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Shaun Alsum	Graduate Student
Rachel Mannino	Postdoc

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David Woodward	Research Associate
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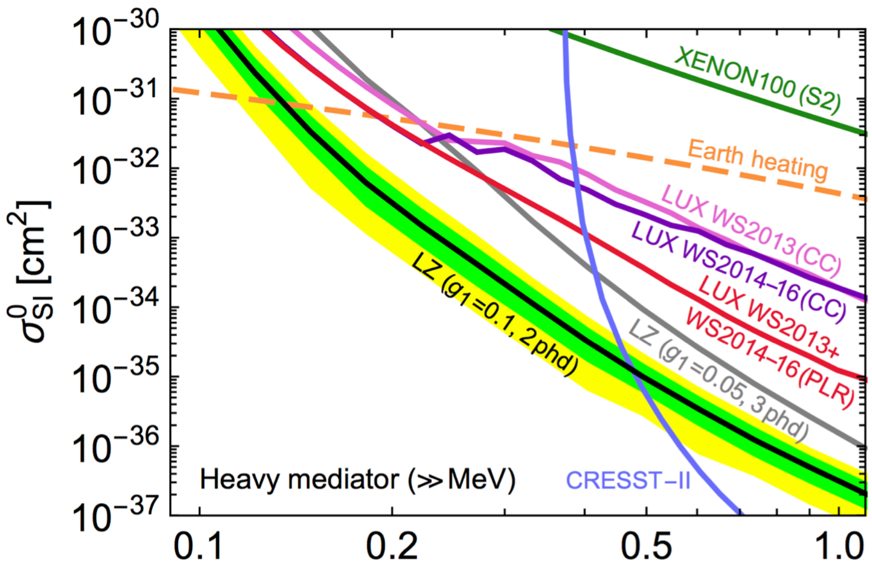
Dongming Mei	PI, Professor

Limits from C. McCabe

PRD 96, 043010 (2017)

- C. McCabe published a paper inferring LUX sensitivity to the sub-GeV signal and calculated limits for LUX & LZ



Earth heating = constraint from
Earth heating by DM annihilation